6 October 2020

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Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

Contributions of the Barcelona Supercomputing Center to the Copernicus Services

Francisco J. Doblas-Reyes

ICREA

Atmosphere Monitoring Service
atmosphere.copernicus.eu

Copernicus
Europe's eyes on Earth

Climate Change Service
climate.copernicus.eu

IMPLEMENTED BY ECMWF

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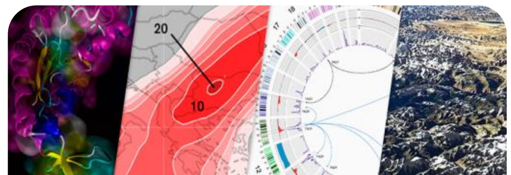
BSC-CNS objectives

Supercomputing services to Spanish and EU researchers



R&D in Computer, Life, Earth and Engineering Sciences

PhD programme, technology transfer, public engagement

BSC-CNS is a consortium that includes

Spanish Government	60%	GOBIERNO DE ESPAÑA / MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD
Catalonian Government	30%	Generalitat de Catalunya Departament d'Empresa i Coneixement
Univ. Politècnica de Catalunya (UPC)	10%	UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

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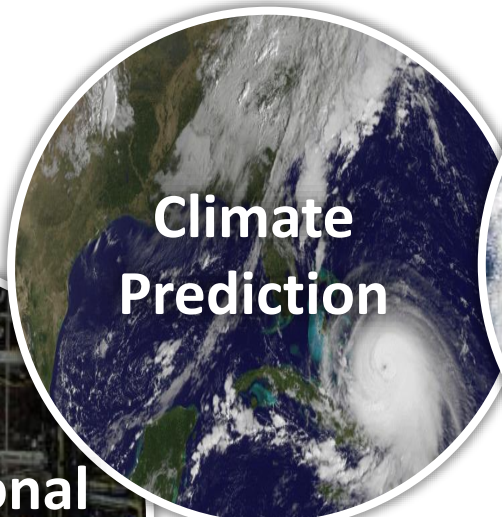
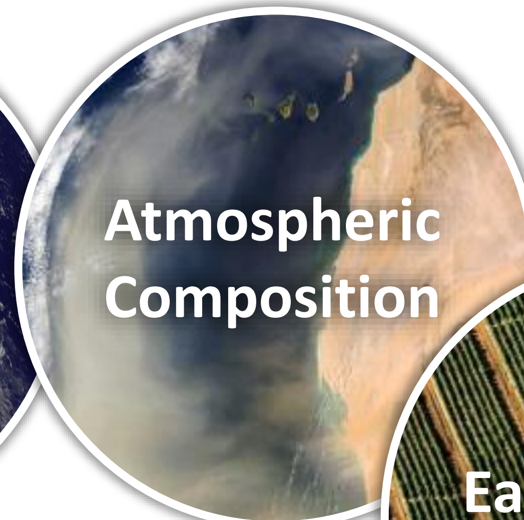
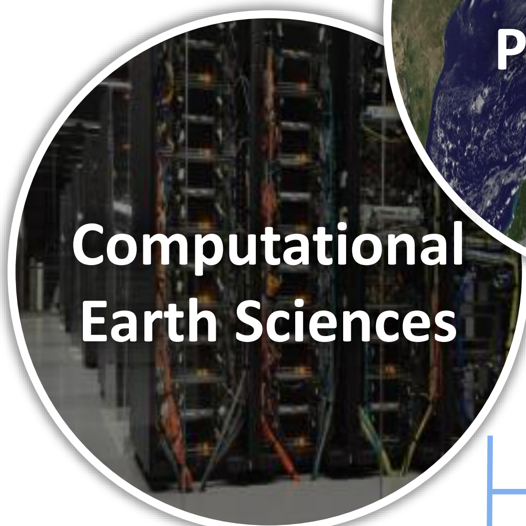
BSC's Earth Sciences Department

Environmental modelling and forecasting using process-based and artificial intelligence models, with a particular focus on weather, climate and air quality. This includes transferring solutions to support the main societal environmental challenges through data applications







- ~120 people
- Funding from EC, Copernicus, private sector, ESA, Spanish and regional governments

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Copernicus services at the BSC

The BSC is involved in the Copernicus services in two different ways: as a contractor that contributes to the development of the services and as a user for research and technology transfer.

ACRONYM	Coordinator	Start date	End date
GLOBAL-87-CMEMS	BSC	01/06/2018	31/05/2019
C3S_34a Lot2 (MAGIC)	KNMI	01/10/2016	31/03/2019
C3S_51 Lot3 (QA4Seas)	BSC	01/07/2016	30/09/2018
CAMS_50	Météo-France	01/10/2018	30/06/2021
CAMS_81	CNRS	01/09/2017	31/08/2020
CAMS_84	KNMI	01/10/2015	30/09/2018
CAMS_84 (2)	KNMI	01/10/2018	31/12/2021
CAMS_95	Capgemini	01/08/2018	31/03/2019
C3S_512	BSC	01/10/2018	30/06/2021
CAMS_43 (2)	HYGEOS	01/04/2019	31/08/2021
C3S_429g	BSC	01/11/2019	31/01/2021
C3S_34c	DWD	01/11/2019	30/06/2021
CAMS_61	TNO	01/01/2020	28/02/2022
CAMS_81 (2)	TNO	01/09/2020	31/12/2021

- As contractor, contracts worth 4 Meuros.
- As user, data from the services employed in tens of European and national projects and several collaboration agreements with private companies.

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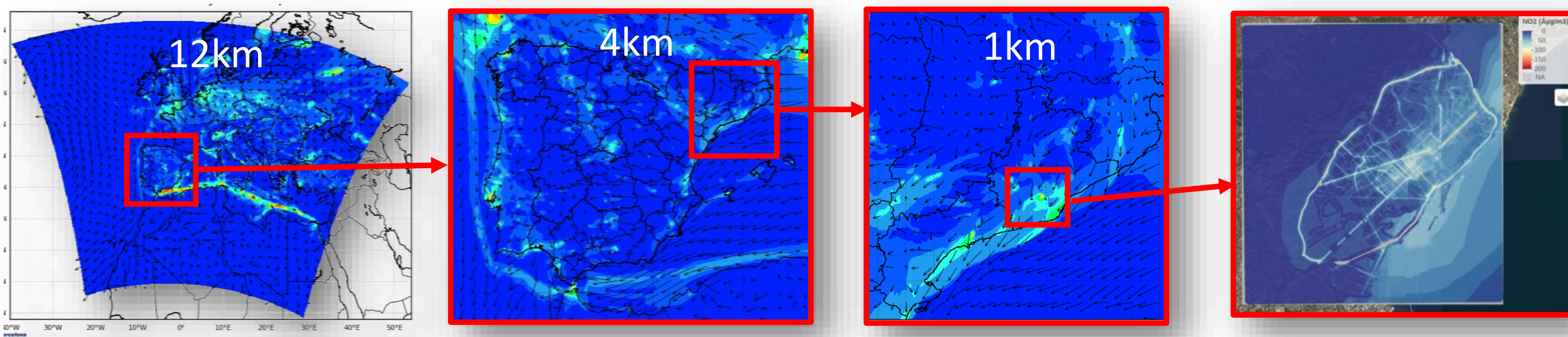
Air quality forecasting at the BSC



Pay et al. (2011; 2012 AE) | Baldasano et al. (2012 AE) | Pay et al. (2014 GMD) | Benavides et al. (2019 GMD)

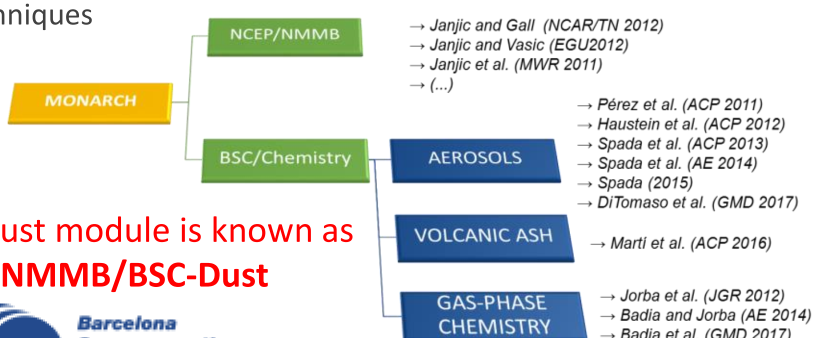
CALIOPE system: air quality forecasts from regional to local scales

In-house model developments

MONARCH model

Multiscale Online Nonhydrostatic Atmosphere Chemistry model

- **Multiscale**: global to regional (up to 1km) scales allowed
- Fully **on-line** coupling: weather-chemistry feedback processes allowed
- Enhancement with a **data assimilation** system and machine learning techniques



The dust module is known as **NMMB/BSC-Dust**

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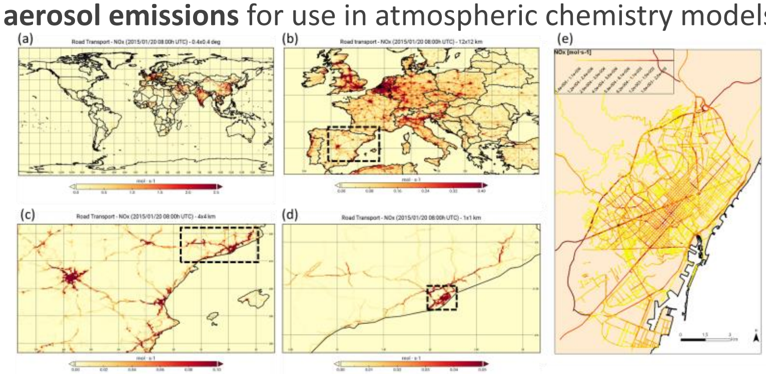
HERMESv3 emission model

A **python-based, open source, parallel and multiscale** emission modelling framework that **processes and estimates gas and aerosol emissions** for use in atmospheric chemistry models.



Guevara et al. (2019, 2020)

Global climate modelling

- Developers of a global high-resolution Earth system model with a high-resolution configuration (10 kms).
- The objective is to understand and predict global climate in time scales of one month to 100 years
- ...and how carbon fluxes will evolve (to inform future actions regarding the Paris Agreement)
- Explore the effectiveness of natural-based climate mitigation strategies, such as reforestation.

EC EARTH3

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As a contractor

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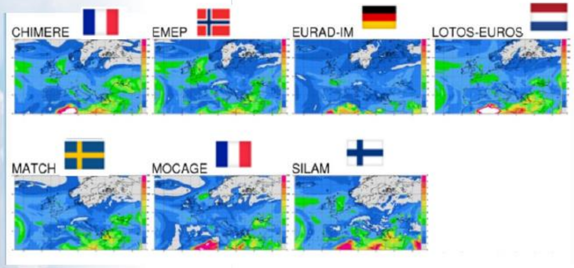
Participation in CAMS contracts

CAMS_50 **Regional production**	Development of a multiscale modeling and forecasting system MONARCH, SDS-WAS, CALIOPE, ICAP
CAMS_81, CAMS_COP_066 **Global and regional emissions**	Development of top down and bottom up emission inventories and models HERMES
CAMS_43, CAMS_61 **Aerosol aspects and data assimilation**	Model data assimilation LETKF DA system
CAMS_84, CAMS_61 **Global and regional a posteriori validation**	Model Evaluation BSC model evaluation tool and harmonisation of observational dataset
CAMS_95 **AsSISt: Aircraft Support & Maintenance Services**	Development of *user-oriented* services for a variety of socio-economic sectors InDust, DustClim, SOLWATT, AQ-WATCH

CAMS_50: Air quality regional forecasts

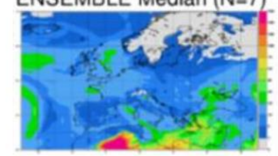
Inputs
Global products
Regional emissions
In situ observations

7 operational AQ models



1 ENSEMBLE model

ENSEMBLE Median (N=7)



How? Median of the individual results for each grid-cell
Why? Reliable, robust, performing

→ **to be used in priority**

Users

New operational models

DEHM (AARHUS University)
GEM-AQ (IEP)

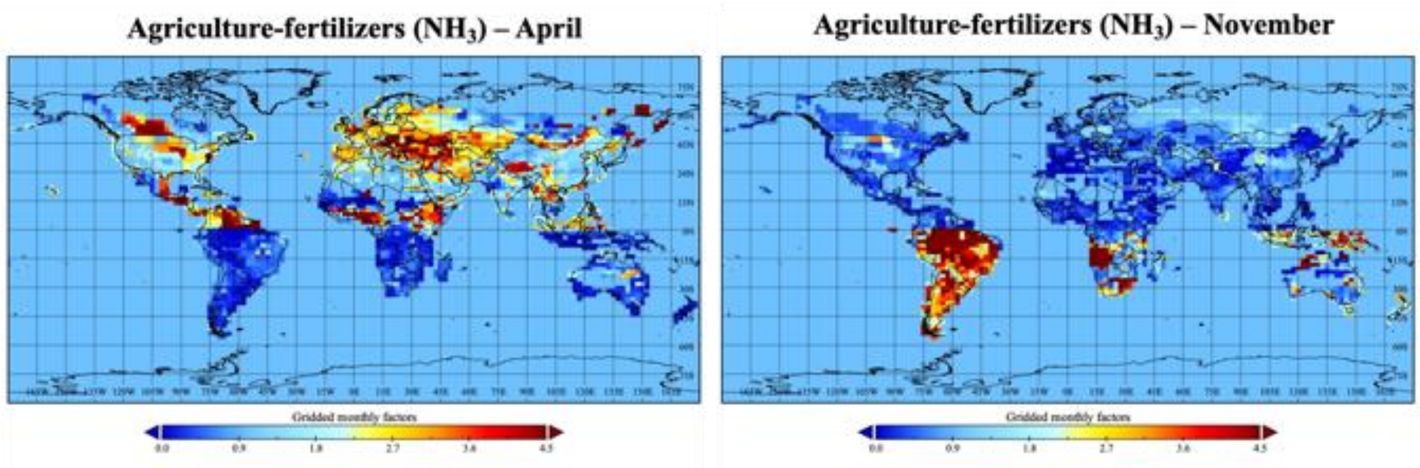
New candidate models

MINNI (ENEA)
MONARCH (BSC)

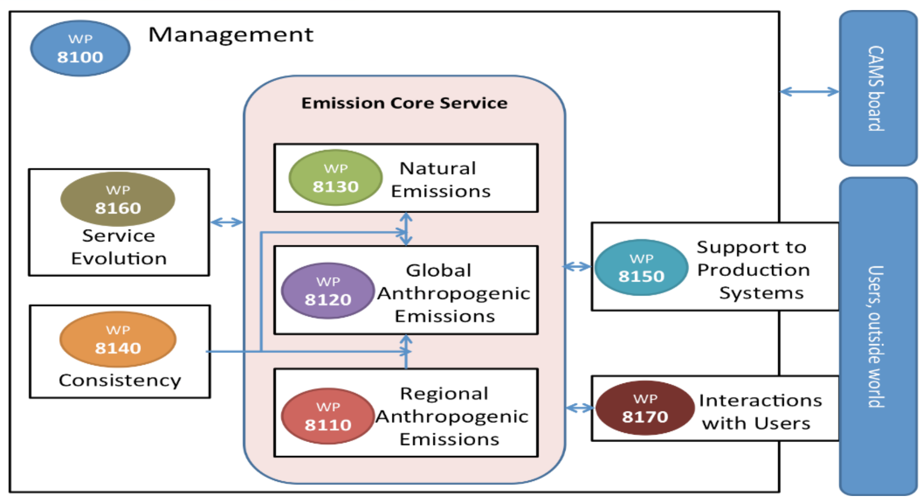
- NRT individual and ensemble 4-day forecasts
- NRT individual and ensemble analyses (DD-1)
- NRT validation and statistics products
- Reanalyses (2014-2017)

CAMS-81: Global and regional emissions

Objective: To provide gridded distributions of annual anthropogenic (global and Europe) and natural emissions and deliver monthly, weekly and diurnal temporal profiles to be combined with the global and regional anthropogenic CAMS emission inventories for air quality modelling.



Fertilizers: influence of national crop calendars



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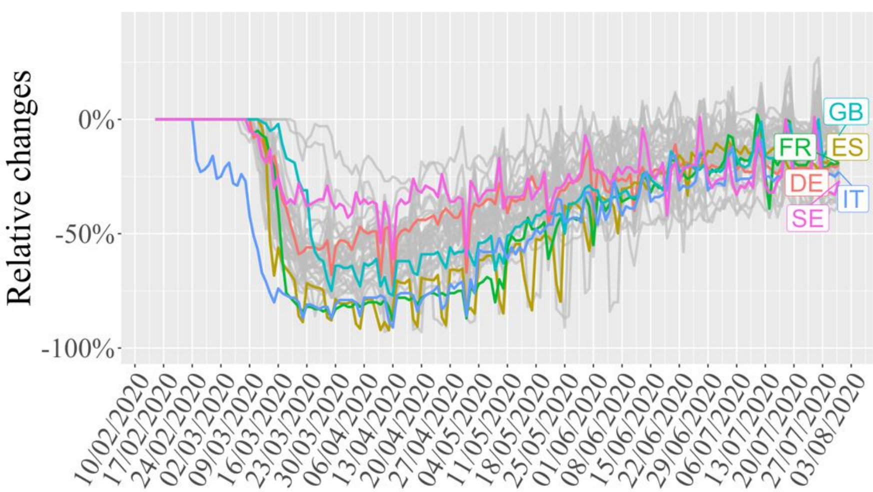
CAMS COP_066

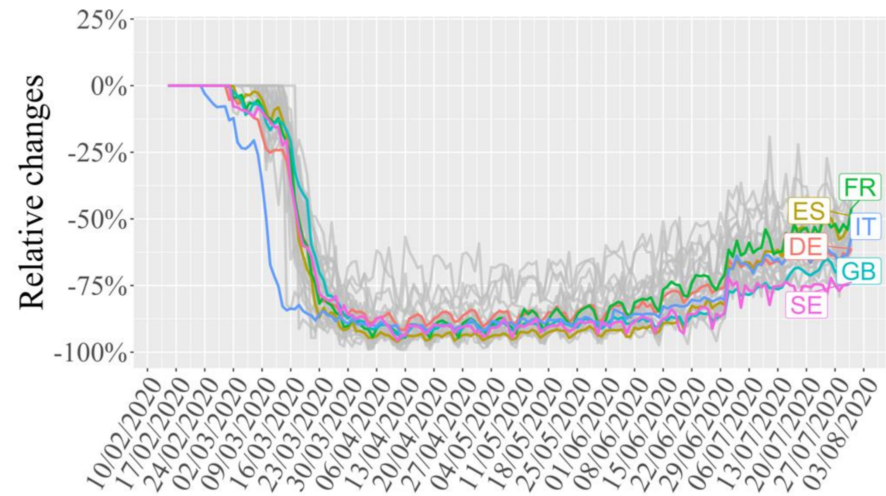
Objective: Development of time-, sector- and country-dependent European emission reduction factors attributable to the COVID-19 lockdown, to quantify the reduction of European emissions and to perform air quality modelling studies:

- Sectors covered: road transport, aviation, manufacturing industry, energy industry, residential and commercial combustion and shipping
- Time period covered 21/02/2020 to 31/07/2020
- Gathering of evidence from a wide range of information sources, including measured activity data, proxy indicators and use of machine learning models

Road transport from Google mobility reports



Aviation from EUROCONTROL statistics



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Guevara et al. (2020 ACPD)

C3S_512: Evaluation and quality control

BSC leads the contract responsible of the development of the evaluation and quality control (EQC) function of the climate data store (CDS) of the Copernicus Climate Change Service (C3S) to:

- Provide a user-led overarching EQC service for the whole CDS
- Provide an independent quality assessment




- CDS datasets: provide information about the technical and scientific quality and fitness-for-purpose, and an assessment of the datasets
- CDS toolbox: assessment of maturity and fitness for purpose of the software provided to explore the datasets
- CDS service: performance assessment of the CDS infrastructure (e.g. speed, responsiveness, system availability)
- CDS users: user requirement assessment to measure users' satisfaction with the CDS. Map evolving user needs into viable user requirements to ensure a user-oriented evolution of the CDS

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C3S_512: Evaluation and quality control

ERA5 monthly averaged data on single levels from 1979 to present

Overview | Download data | Quality assessment | Documentation

This is a new feature, work in progress. Should any inconsistency be found, please report to copernicus-support@ecmwf.int

The CDS datasets are independently assessed by the Evaluation and Quality Control (EQC) function of C3S. EQC encompasses a framework of processes aimed to assure technical and scientific quality harmonized across all dataset types available through the CDS. During the EQC process, the documentation provided with the dataset is scrutinized and data are checked for usability and reliability.

Variable:

2m temperature

▾ Variable: 2m temperature

Latest updated on 24/06/2020

INTRODUCTION	USER DOCUMENTATION	ACCESS	INDEPENDENT ASSESSMENT
Dataset overview	User guide	Toolbox compatibility	Data check
Temporal and spatial coverage and resolution	Scientific methodology	Archive	Expert evaluation
Providers	Uncertainty quantification		Dataset maturity
Dataset version	Validation		Key strengths and limitations
Data update	Inter-comparison		

Entries with the mark | display content that is specific for the variable selected

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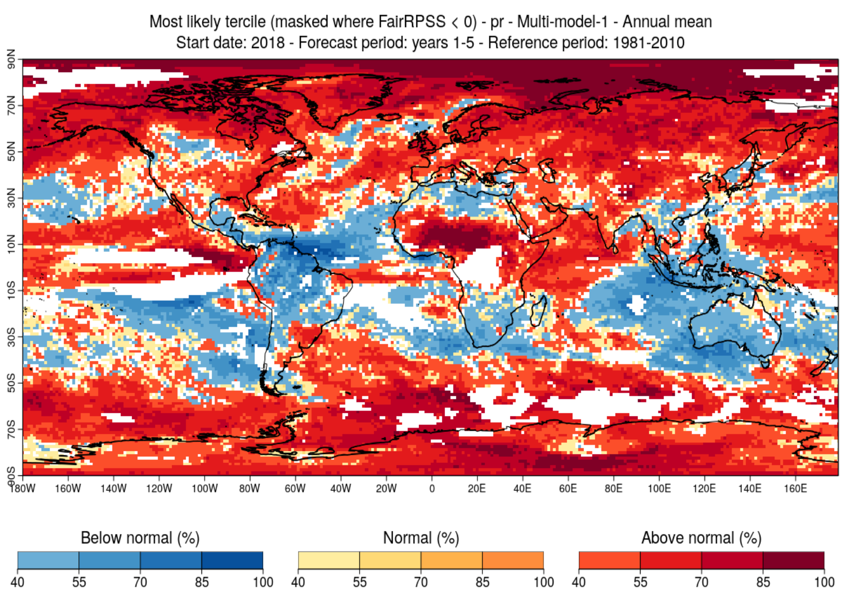
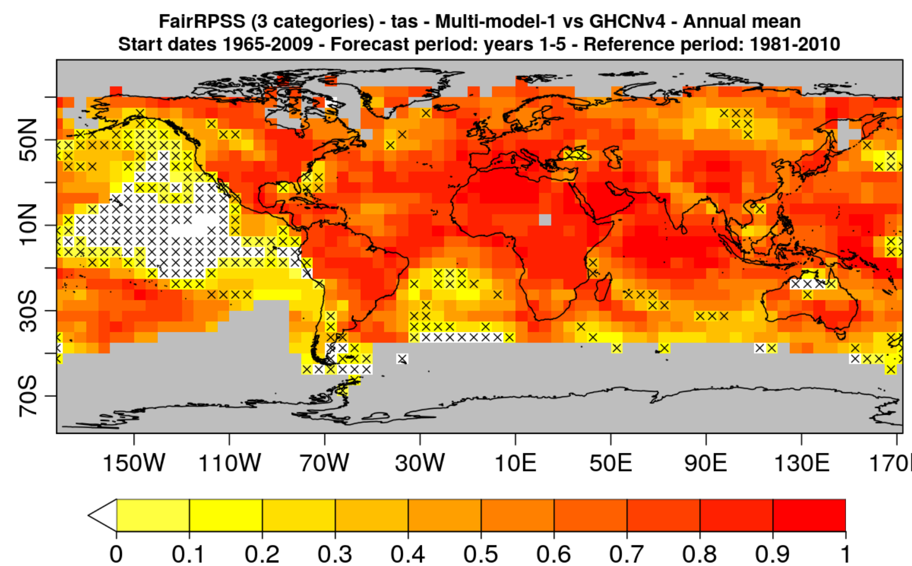
C3S_34c: Global decadal climate predictions

BSC, as one of the WMO recognised global producing centres of decadal predictions, contributes with the definition of standards for decadal predictions data and products, the evaluation of the European multi-model and the illustration of the decadal prediction use in the agricultural sector (in collaboration with JRC-Ispra).





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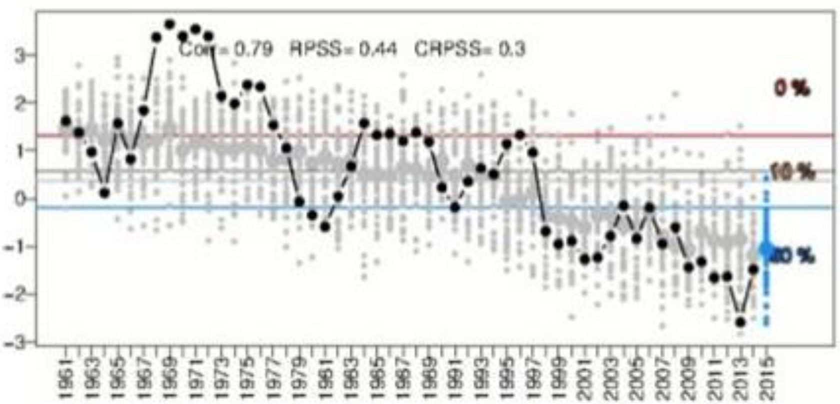
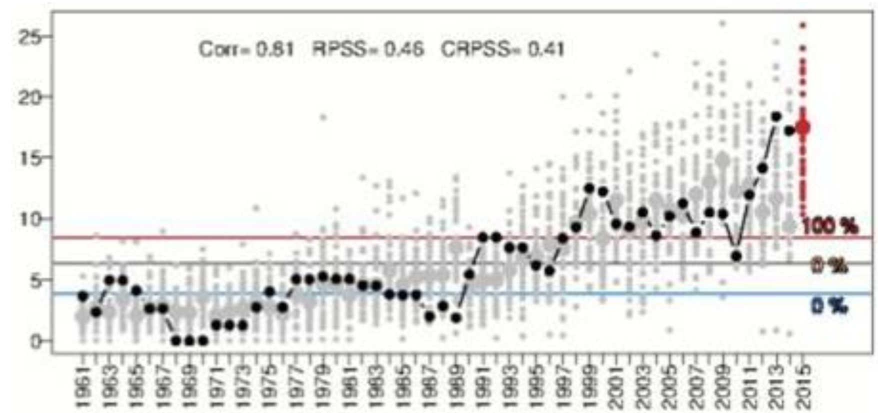
SPEI6



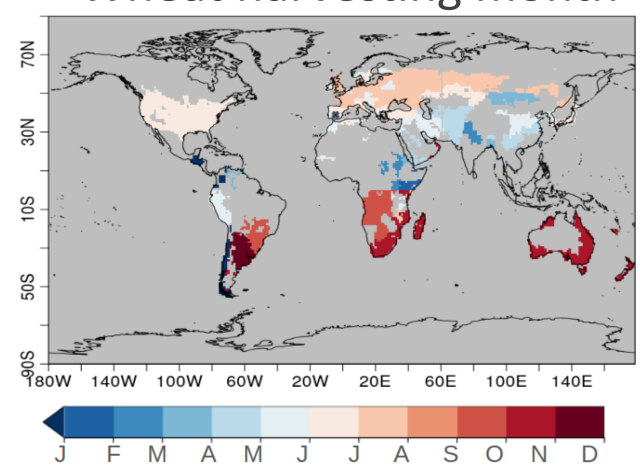
HMDI3



Indicators:

- Drought: Standardized Precipitation Evapotranspiration Index (SPEI6)
- Heat Stress: Heat Magnitude Day Index (HMDI3)

Wheat harvesting month



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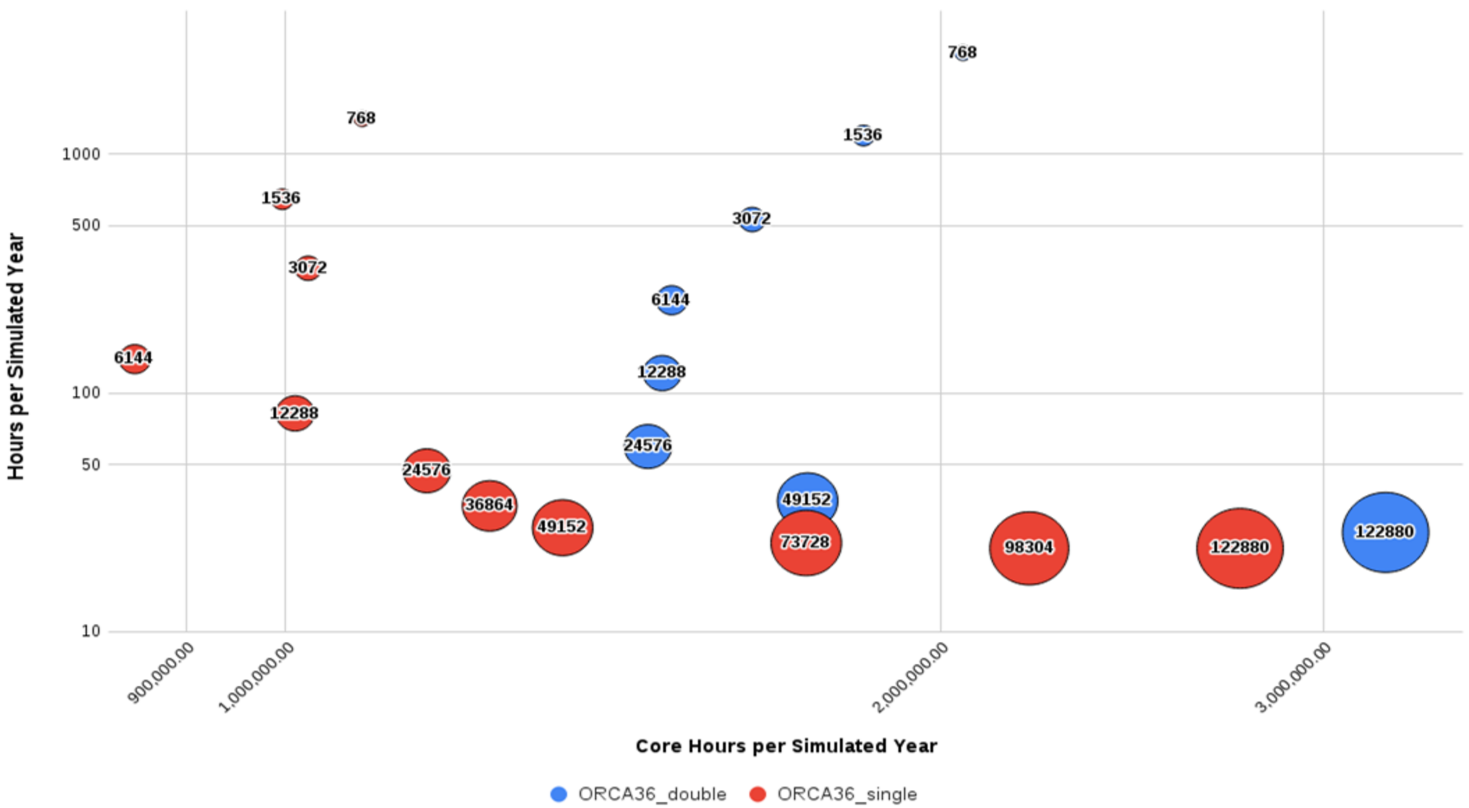
CMEMS: Mixed precision and high resolution

Mixed precision in the NEMO ocean model may allow to achieve 1 SYPD with 3 km global resolution on current architectures, but needs something close to exascale for production. Up to x1.9 speedup on memory bandwidth bound configurations. NEMO memory usage is not scaling though. Data is an issue: restarts of ~1 Tb.



As a user

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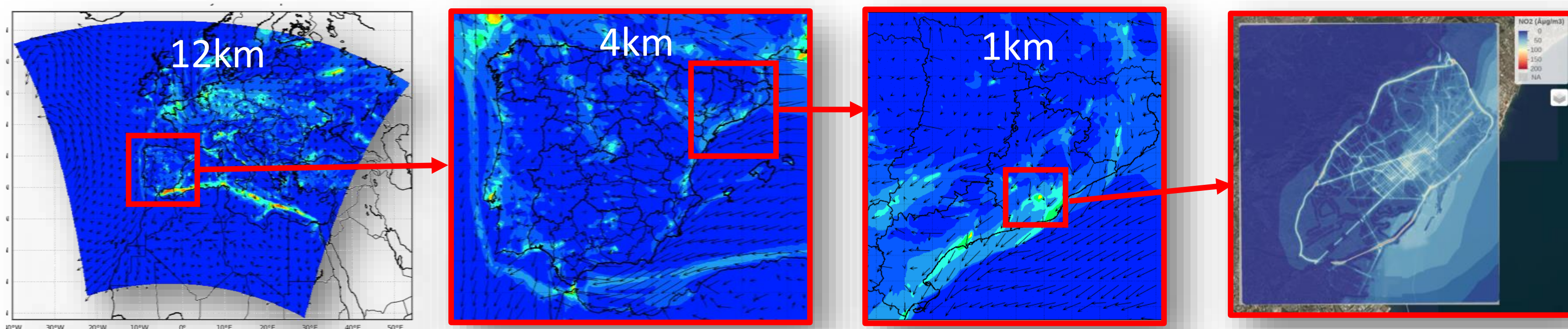
Air quality: CAMS boundaries and emissions



Pay et al. (2011; 2012 AE) | Baldasano et al. (2012 AE) | Pay et al. (2014 GMD) | Benavides et al. (2019 GMD)

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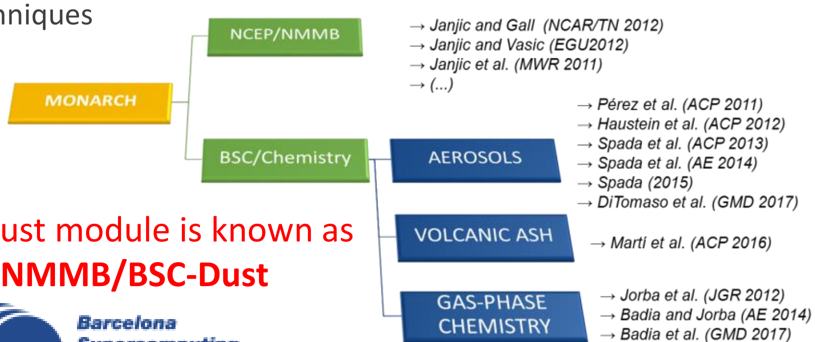

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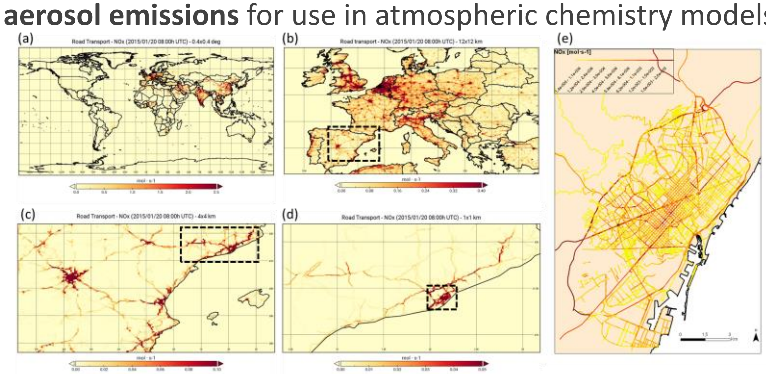
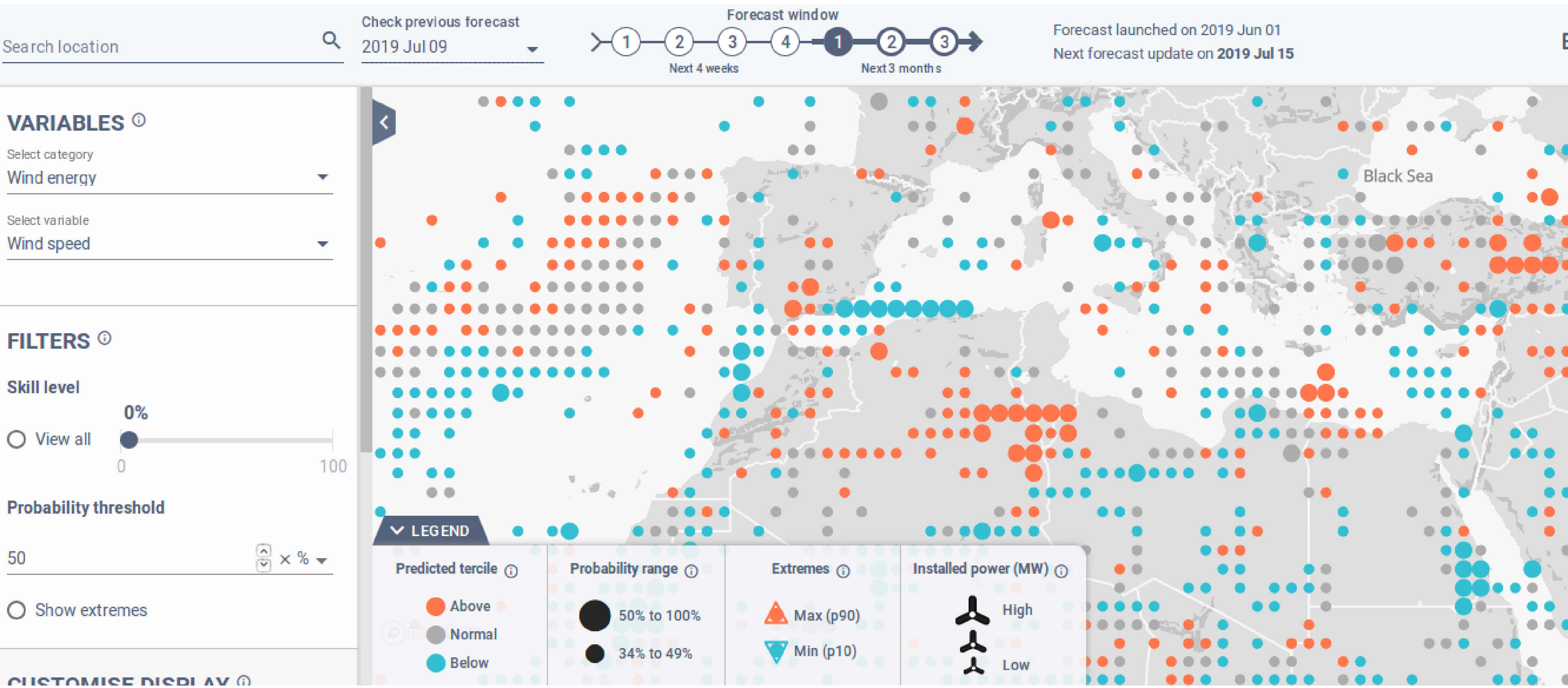


Guevara et al. (2019, 2020)

Prototypical services: energy services

Climate service for the renewable energy sector based on C3S forecasts processed and displayed operationally for the industry using user engagement practices.



Publicly available (under registration) from http://s2s4e.eu/dst

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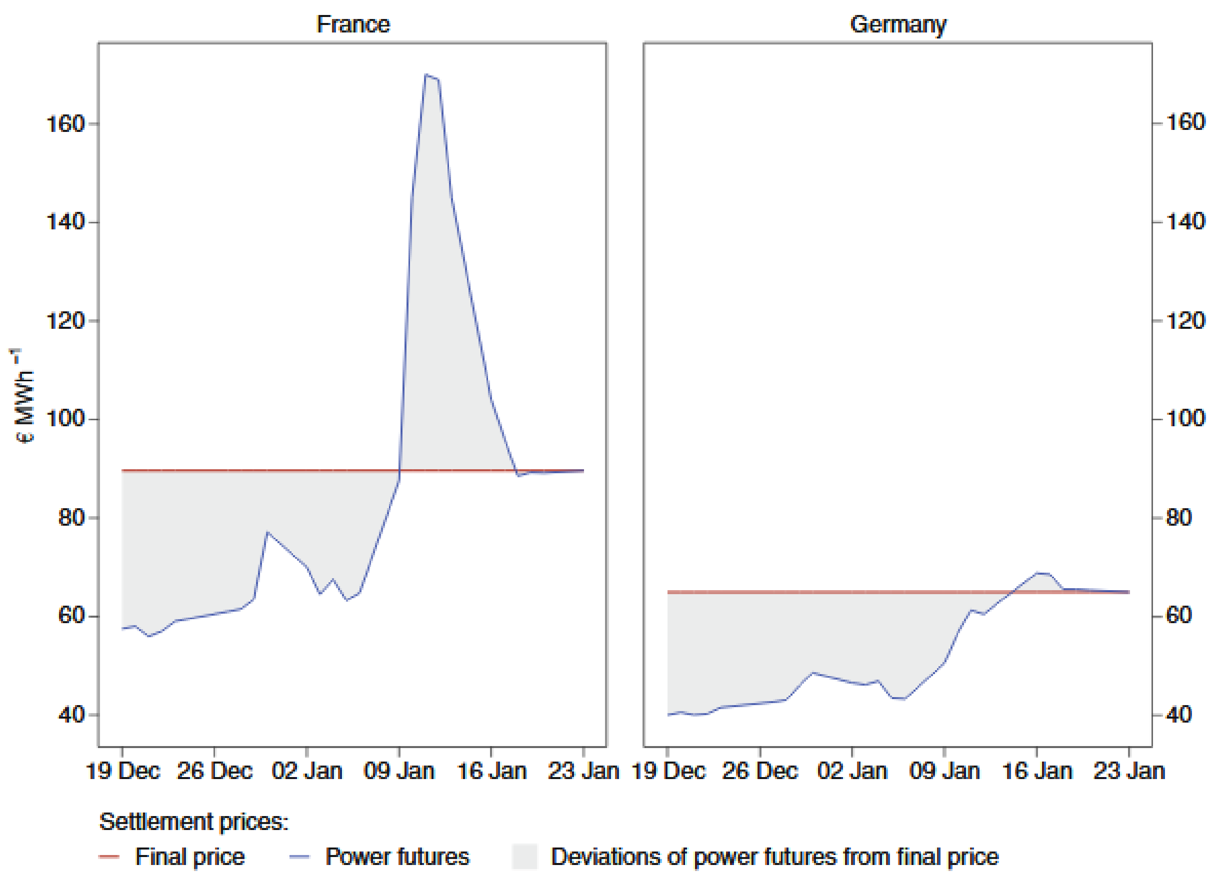
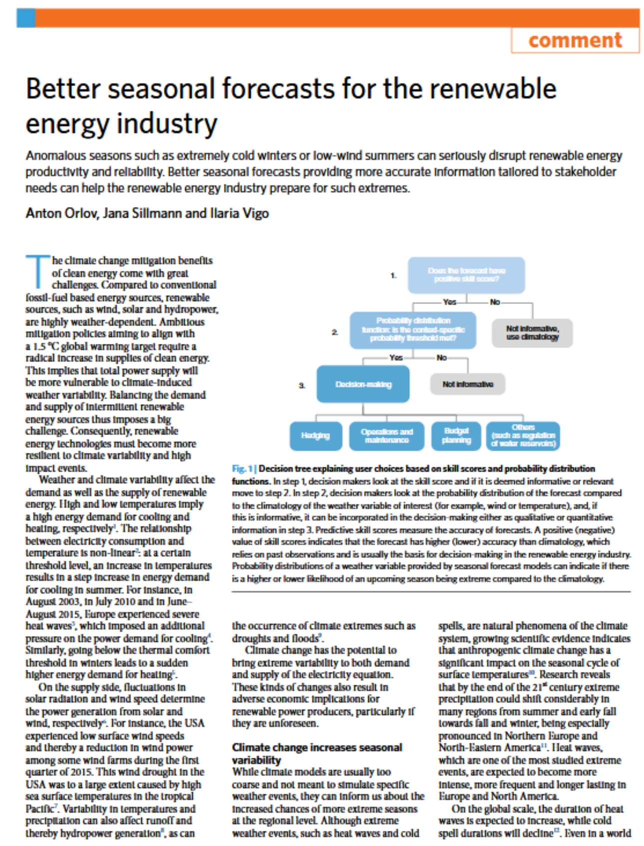
S2S4E
Climate Services for Clean Energy

Economic assessment: energy services

Final and power futures settlement prices in Germany and France for week 3 in 2017 during a severe cold spell period.





comment

Better seasonal forecasts for the renewable energy industry

Anomalous seasons such as extremely cold winters or low-wind summers can seriously disrupt renewable energy productivity and reliability. Better seasonal forecasts providing more accurate information tailored to stakeholder needs can help the renewable energy industry prepare for such extremes.

Anton Orlov, Jana Sillmann and Ilaria Vigo

The climate change mitigation benefits of clean energy come with great challenges. Compared to conventional fossil-fuel based energy sources, renewable sources, such as wind, solar and hydropower, are highly weather-dependent. Ambitious mitigation policies aiming to align with a 1.5 °C global warming target require a radical increase in supplies of clean energy. This implies that total power supply will be more vulnerable to climate-induced weather variability. Balancing the demand and supply of intermittent renewable energy sources thus imposes a big challenge. Consequently, renewable energy technologies must become more resilient to climate variability and high impact events.

Weather and climate variability affect the demand as well as the supply of renewable energy. High and low temperatures imply a high energy demand for cooling and heating, respectively[1]. The relationship between electricity consumption and temperature is non-linear[2]: at a certain threshold level, an increase in temperatures results in a step increase in energy demand for cooling in summer. For instance, in August 2003, in July 2010 and in June–August 2015, Europe experienced severe heat waves[3], which imposed an additional pressure on the power demand for cooling[4]. Similarly, going below the thermal comfort threshold in winters leads to a sudden higher energy demand for heating[5].

On the supply side, fluctuations in solar radiation and wind speed determine the power generation from solar and wind, respectively[6]. For instance, the USA experienced low surface wind speeds and thereby a reduction in wind power among some wind farms during the first quarter of 2015. This wind drought in the USA was to a large extent caused by high sea surface temperatures in the tropical Pacific[7]. Variability in temperatures and precipitation can also affect runoff and thereby hydropower generation[8], as can the occurrence of climate extremes such as droughts and floods[9].

Climate change has the potential to bring extreme variability to both demand and supply of the electricity equation. These kinds of changes also result in adverse economic implications for renewable power producers, particularly if they are unforeseen.

Climate change increases seasonal variability

While climate models are usually too coarse and not meant to simulate specific weather events, they can inform us about the increased chances of more extreme seasons at the regional level. Although extreme weather events, such as heat waves and cold spells, are natural phenomena of the climate system, growing scientific evidence indicates that anthropogenic climate change has a significant impact on the seasonal cycle of surface temperatures[10]. Research reveals that by the end of the 21st century extreme precipitation could shift considerably in many regions from summer and early fall towards fall and winter, being especially pronounced in Northern Europe and North-Eastern America[11]. Heat waves, which are one of the most studied extreme events, are expected to become more intense, more frequent and longer lasting in Europe and North America.

On the global scale, the duration of heat waves is expected to increase, while cold spell durations will decline[12]. Even in a world

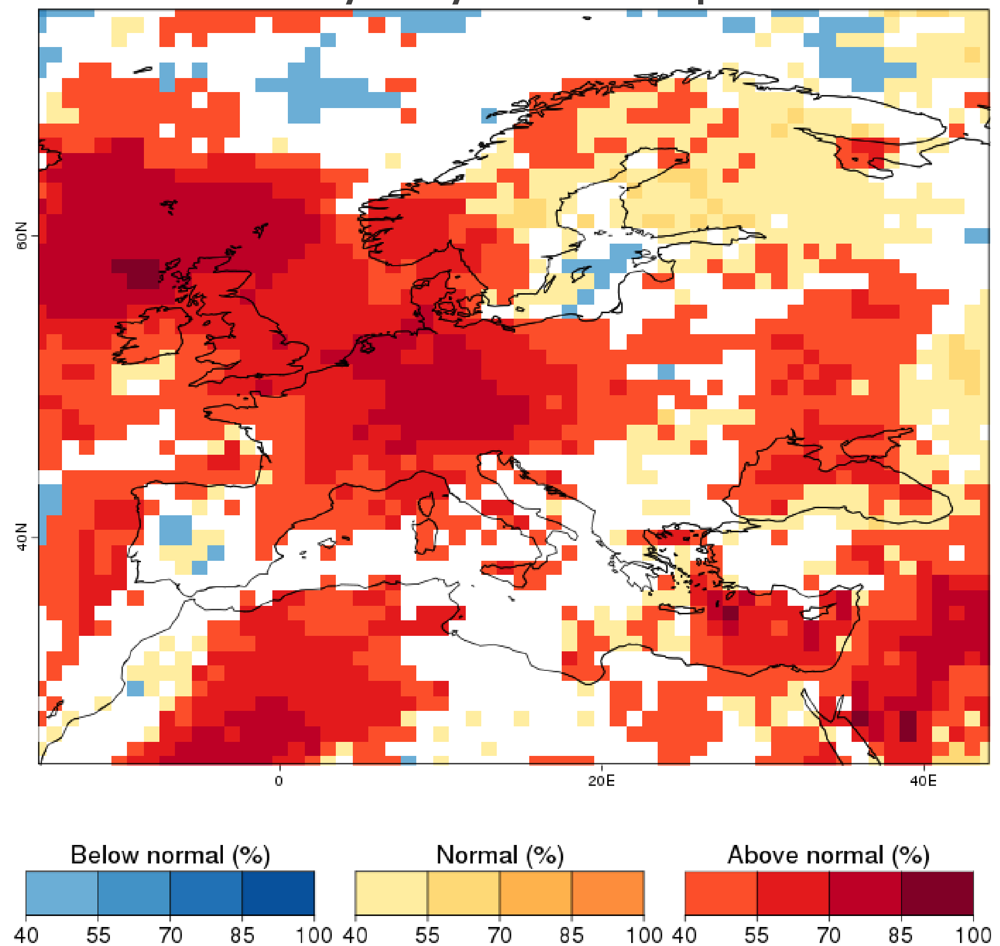
Fig. 1 | Decision tree explaining user choices based on skill scores and probability distribution functions. In step 1, decision makers look at the skill score and if it is deemed informative or relevant move to step 2. In step 2, decision makers look at the probability distribution of the forecast compared to the climatology of the weather variable of interest (for example, wind or temperature), and, if this is informative, it can be incorporated in the decision-making either as qualitative or quantitative information in step 3. Predictive skill scores measure the accuracy of forecasts. A positive (negative) value of skill scores indicates that the forecast has higher (lower) accuracy than climatology, which relies on past observations and is usually the basis for decision-making in the renewable energy industry. Probability distributions of a weather variable provided by seasonal forecast models can indicate if there is a higher or lower likelihood of an upcoming season being extreme compared to the climatology.

Orlov et al. (2020 Nature Energy)

Indicators: wine production services

In 2011 the Douro valley experienced mild temperatures during the whole grape growth cycle leading to a relatively late bud-break and a smooth, regular vegetative growth with hardly any disease pressure.

Probability of the most likely tercile of growing season average temperature. Start date 2011, C3S SEAS5, bias adjusted data.



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MED-GOLD

VISCA
VINEYARDS INTEGRATED SMART CLIMATE APPLICATION

Full chain: logistics services

Logistics and selling of seasonal products are heavily affected by climate variability. The objective of the research agreement to shape the service is twofold:

- Work with historical data (pool of business and ERA5 climate data) to understand how climate variability affects a range of decisions.
- Translate this knowledge into a prototype of action-oriented service based on CFSv2 for sub-seasonal time-scales and C3S SEAS5 for seasonal time-scales.
- Walk along the path towards climate adaptation across the jungle of climate data and information.

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